

An Analysis of Nurses' Cognitive Work: A New Perspective for Understanding Medical Errors

**Patricia Potter, Laurie Wolf, Stuart Boxerman, Deborah Grayson,
Jennifer Sledge, Clay Dunagan, Bradley Evanoff**

Abstract

Health care researchers agree that the acute care hospital environment is filled with numerous distractions. Within this environment, professional nurses make clinical judgments about their patients, whose conditions may change minute by minute. As a result, nurses constantly organize and reorganize the priorities and tasks of care to accommodate patients' fluctuating status. To date, little attention has been given to how interruptions in the workplace influence nurses' ability to anticipate and carry out the actions directed by their clinical judgment. This paper describes an ongoing research study aimed at exploring the effect of interruptions on the cognitive work of nursing. A methodology combining human factors techniques and qualitative observation of nurses in practice has produced a cognitive pathway. The pathway is a unique visual graphic that offers a perspective of the nature of nurses' work and the relationship interruptions and cognitive load may have on omissions and errors in care. The approach to analyzing the cognitive work of nurses has important implications for understanding the origins of medical errors.

Introduction

The occurrence of medical errors within the acute care environment, as reported in *To Err Is Human: Building a Safer Health System*, has raised national concerns for patient safety.¹ The Agency for Healthcare Research and Quality has made the effects of health care working conditions on patient safety a major research initiative.² Understanding the nature of medical errors is a daunting task. At the center of this conundrum are registered nurses (RNs) and the nature of their practice.

Nurses are responsible for the daily monitoring and management of the quality of health care delivered to patients.³ The nurse's role includes immediate detection and intervention when patients' clinical conditions change. Expert nursing practice requires not only psychomotor and affective skills, but complex thinking processes such as making inferences and synthesizing information to choose a course of action.⁴ Nurses constitute the surveillance system for early detection of patient complications and problems, and are in the best position to initiate actions that minimize negative patient outcomes.⁵ However, clinical reasoning and decisionmaking are complicated by the fact that nurses care for

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multiple patients within environments that are fast-paced and unpredictable, and that offer unreliable access to resources and information.⁶ To date, human factors research aimed at understanding the effects of working conditions on patient safety has failed to analyze nurse decisionmaking activities and the influence of environmental variables. New ways of understanding the complexity of registered nurses' work and the relationship between environmental barriers and distractors is needed in order to understand the origin and nature of medical errors.

The expertise of human factors engineers has been widely used in industry to improve the operation of complex systems, reduce cognitive errors related to poor person-machine interfaces, and increase the comfort level of workers. Objectives of human factors engineering (HFE) are to maximize human and system efficiency, human well-being, and quality of life.⁷ HFE techniques were used widely when hospitals underwent re-engineering in the 1990s and were beneficial in improving health care processes such as laboratory specimen acquisition and medication dispensing. However, Pepitone⁸ warns that traditional HFE or control-based engineering methods for improving performance are unsuccessful in analyzing knowledge and service work such as nursing practice. The author suggests this lack of success is because the work of nursing is self-paced, discretionary, and nonlinear. Although HFE techniques provide valuable data about the psychomotor activities of nursing care, time measurements, and motion patterns, an alternative method is needed to study the nature of clinical decision-making.

Clinical reasoning and decisionmaking enable nurses to analyze information relevant to patient care. A nurse who moves between multiple patient rooms to attend to patients' changing clinical situations engages in a recursive cognitive process that uses inductive and deductive cognitive skills.⁹ Qualitative observation is an appropriate methodology for capturing the process for how nurses interact with patients and health care providers in the conduct of clinical decisionmaking and patient care. This paper presents a new research methodology that combines qualitative observation and HFE analysis in studying the nursing care process. The product of this methodology is a cognitive pathway, a unique visual graphic that offers a new way to look at the cognitive work of nurses, and begins to reveal how cognitive workload and interruptions may predispose a nurse to make errors.

Methods

Our research team has been studying working conditions on acute care nursing units over the past two years. Initially, we focused on traditional HFE techniques to analyze the work of nurses delivering patient care and identify the presence of environmental disruptions. The initial aim was to determine if factors within the environment created barriers to the nurses' ability to care for patients. Results revealed a lack of information pertaining to the clinical decisionmaking of nursing and the context in which nurses monitored patients, recognized clinical problems, and took action. Thus, our methodology evolved as we combined HFE

techniques with qualitative observation of nurses in practice, to gather rich detail regarding the cognitive intent of nursing activities.

This report focuses on results taken from observations of three registered nurses (RNs) who are part of our larger study. A human factors engineer and a nurse-researcher jointly and simultaneously observed RNs during the first 8–10 hours of their routine 12-hour day shift. The RNs worked on a general acute medicine unit and a neuromedicine unit and averaged 13.4 years of experience (range: 5 months to 20 years).

HFE quantitative techniques

A Human Factors Engineer collected data to identify activities performed by an RN during an assigned work shift. Physical activities of the RN were noted through direct observation. Location and duration of each activity were documented. Data was used to create a link analysis, which depicts the physical motion of the RN between each location on the nursing unit. Interruptions were counted with special notation of interruptions that occurred in the medication room.

A spreadsheet with each physical activity and the time of occurrence was developed to create a task analysis—a systematic breakdown of a job or set of work activities into specific elements. The analysis includes task duration, frequency, environmental conditions, and all factors required for activities. Each activity was assigned to a major category of task (e.g., documentation, consultation), with subtasks (e.g., computer data entry, or consultation with physician or family member) added as needed to completely describe the task. The amount of time spent in each major task category was calculated. Additional analyses included time and motion review, and workflow evaluation.

Qualitative techniques

The nurse-researcher conducted a qualitative analysis with the focus of understanding the activities of patient care within the context of the nursing process. RN observations began during the change-of-shift report, allowing the researcher to identify the patient care priorities communicated by the previous shift. The researcher accompanied the RN to each patient's room, observing the RN's activities, including any patient interaction. As the RN left each patient's room, the researcher asked the RN to identify patient problems and care priorities for the shift. This enabled the researcher to track the ability of the RN to complete identified priorities of care and associated activities. The researcher shadowed the RN for the remainder of the observation period to record all nursing process activities performed, as well as the intent or rationale for each activity.

Each activity performed by the RN was categorized into one of five steps of the nursing process (assessment, diagnosis, planning, intervention, and evaluation), which is the standardized approach used by nurses to identify, diagnose, and treat human responses to health and illness.¹⁰ This was done to observe how and to what extent the five steps of the nursing process were

completed. Assessment activities included inquiries made by the RN pertaining to the patient's initial and ongoing physical and psychological conditions, and physical observations and measurements. Nursing diagnosis data included the patient problems/priorities identified by the RN. Planning activities included consultation and referral activities with patients, physicians or assistive staff. Intervention activities included direct and indirect care measures, such as medication preparation and administration; symptom management; and documentation. Evaluation activities included inquiries or measurements made to determine the patient's response to an intervention.

Merging quantitative and qualitative methods

After each observation period, the two researchers met to combine data. Each session began with a review of data to verify that the time and location of each activity was recorded as being the same. Discrepancies were resolved using a consensus-based approach. Each activity was reviewed to understand the intent and significance of the RN's actions. Following this, the nurse-researcher classified each activity into the appropriate nursing process step. The sequence of nursing process steps was mapped to develop the cognitive pathway.

The second phase of the analysis was to identify and confirm interruptions. Perspectives of the researchers differed as to what comprised an interruption. The HFE definition of an interruption was anything that stopped the RN from performing an immediate task. This definition aligns with the HFE researcher's focus of each activity or task being unique and, once stopped, constitutes an interruption. The nurse-researcher defined interruptions as actions on the part of other staff or occurrences from the environment that disrupted the RN's performance of a nursing process activity. The researcher focused on the intent of each activity and whether it was part of the clinical decisionmaking process. For example, if a doctor stopped a nurse in a hallway to give an update on patient status, the HFE classified it as an interruption. However, within the nursing care context this information was needed as part of patient care and was classified as a planning activity, specifically a consultation. Subsequently, the latter definition was used because the methodology incorporated the nursing process context, and best reflected how activities on the pathway were disrupted.

The third phase of data analysis was to identify omissions in care. By tracking the priorities and activities of care that an RN identified, the researchers determined what activities remained incomplete at the end of an observation period. A tentative time was identified for when the omitted activity should have been performed.

The final phase of analysis involved tracking the number of activities the RN anticipated performing throughout the course of the work shift. RNs constantly reorganize priorities to determine which patient care activities to complete at any given time. This requires a concomitant processing and cognitive storage of information.¹¹ Information in the RN's working memory must become or remain active, particularly when new information competes for attention. Researchers calculated a cognitive stacking measure, defined as an accumulative measure for

quantifying tasks and priorities a nurse needs to perform at any given time, for a group of patients during an assigned shift. The cognitive stacking measure is calculated by tracking the patient care tasks and priorities that accumulate over time. Any activity or priority that is identified as needing to be performed is added sequentially. When the RN completes an activity or priority, a number is subtracted from the measure. This allows researchers to identify the cognitive stacking load at any given time. In this manner, a cognitive stacking measure can be obtained at the time an omission or error in care is committed.

Results

The qualitative and quantitative HFE data were paired to provide a complete picture of the RN's activity for the observation period. Activities performed by each RN were quantified with a task analysis. Data on start time, finish time, and duration were compiled for each activity. All tasks performed by the RNs were grouped into six major categories, with the time spent by all nurses averaged for each category.

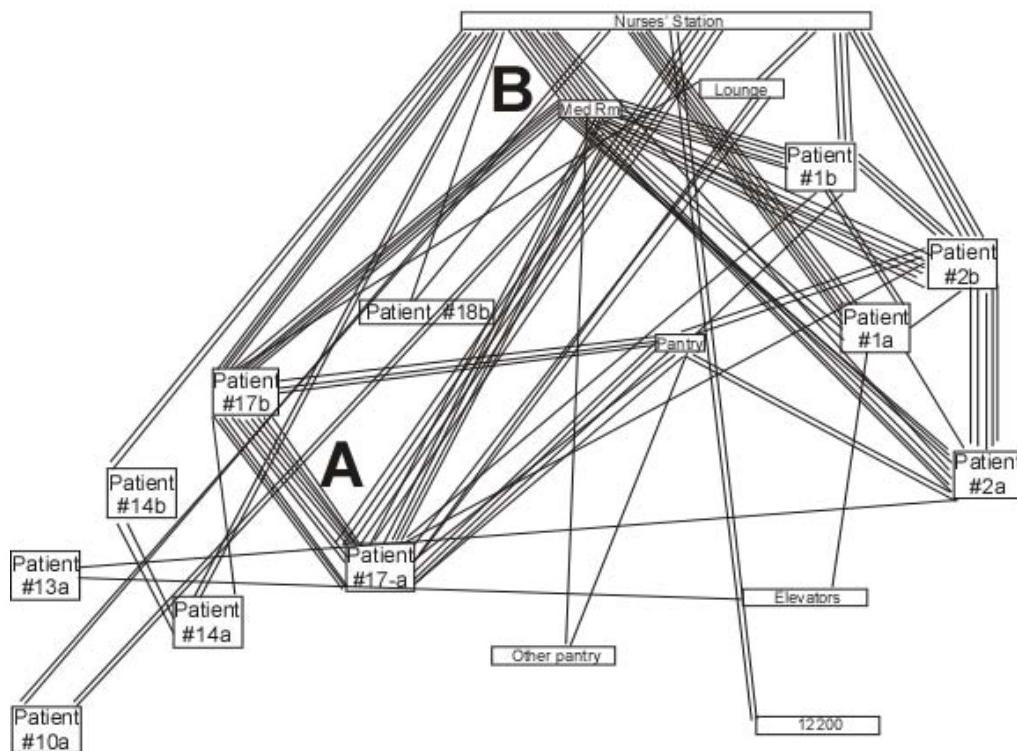
The three RNs spent the majority of time in direct communication with health care team and family members (26 percent). Approximately 22 percent of the RNs' time was spent in direct patient contact performing tasks such as assessments, treatments, and education. Documentation included tasks such as computer data entry, review of medical records, and order entry (21 percent). Medication administration tasks included preparation and administration of medications (17 percent). Relatively little time was spent searching for hospital supplies and equipment (5 percent).

The HFE researcher constructed a diagram of each RN's motion and task patterns in the form of a *link* analysis (Figure 1). Task sequences were broken down into motion patterns revealing repetitive links or pathways taken by the RN on the nursing unit. A *link* is the sequence or connection between two elements of a task. The total number of links was summarized and grouped, then the number of activities that occurred for each link was counted. The link analysis helps to determine the most frequent RN motions.

During their observation, the RNs averaged 157 links, when extrapolated to a 12-hour shift. For every link or motion to a new area, there were never more than two physically observable tasks performed in that location. All RNs had at least two occurrences of a heavy traffic pattern. We defined a heavy traffic pattern as eight or more trips to the same area in a shift. In Figure 1, the RN had a total of 128 links with the heaviest traffic patterns having 10 identical links, which occurred when the RN walked between patient 17a and 17b 10 different times. In traditional HFE evaluation, a heavy traffic pattern often indicates waste or inefficiency.¹² However, before a determination of inefficiency can be made, a thorough understanding of the causation of the heavy traffic pattern must be explored. In this example, the heavy traffic pattern occurred because both patients required frequent attention for ongoing oxygenation problems. The RN's repetitive motions represent efficiency because the RN was frequently monitoring

each patient, administering interventions, and evaluating treatment responses. The intent of the RN's actions was captured in the qualitative observations.

Figure 1. Link analysis for RN #1



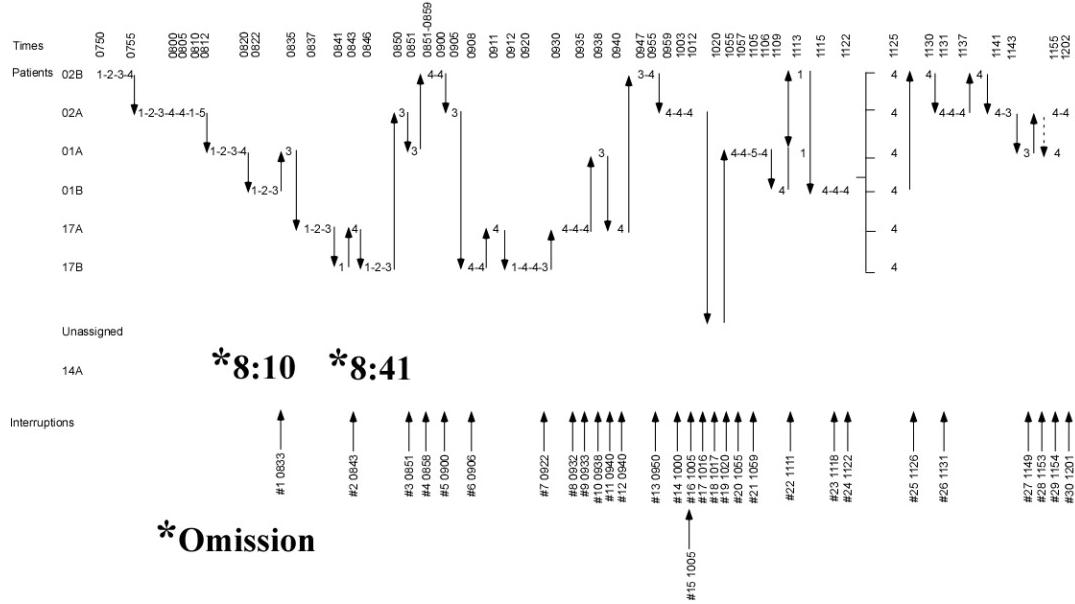
Each line represents the RN's movement from one location to another. For example, RN moves between patients 14A and 14B twice.

The qualitative analysis measured the pattern and sequence of steps of the nursing care process. The researcher maintained extensive notes on the RN's patient care activities to track and categorize each step of the nursing process. It became clear early on that the merging of HFE and qualitative data better represented the nature of an RN's cognitive work. The manner in which an RN manages care for multiple patients is not one-dimensional. An RN is challenged to identify, anticipate, and then act on the patterns of responses patients present during the course of a given shift of care. Any one patient situation can drastically alter how an RN must choose to organize his or her time.

Combining HFE and qualitative data resulted in a cognitive pathway (Figure 2), which displays a graphic sequence of the nursing process steps conducted by the RN for all assigned patients over an observational period. Each number on the pathway represents a step of the nursing process: (1) assessment; (2) nursing diagnosis; (3) planning; (4) intervention; and (5) evaluation. A horizontal hatch mark between each step of the process depicts the flow from one step to another. When a nurse shifted focus from one patient to another, we called this phenomenon a cognitive shift as depicted by arrows on the pathway. A cognitive

shift is a shift in attention from one patient to another during the conduct of the nursing process. The RNs averaged 76.6 cognitive shifts for their shift of care, thus averaging 9.3 cognitive shifts per hour. A cognitive shift does not necessarily represent physical movement on the part of the RN; instead it represents a conscious shift in thinking from one patient to another.

Figure 2. Cognitive pathway for RN #1



Each arrow represents a change in cognitive focus between one patient and another. For example, at 7:55, the RN shifts attention from patient 2B to patient 2A.

Steps in the nursing process are represented in a timeline as they occur along the pathway. The top horizontal line shows the time intervals for observed activities. The bottom horizontal row of vertical arrows and designated times shows the occurrence of interruptions. Interruptions were categorized and their incidence was recorded in relation to when steps of the nursing process were performed. Table 1 offers an example of the interruptions in the observation of RN #3. Interruptions were classified as either delays, direct care disruptions, or indirect care disruptions. A delay was an interruption occurring at a time when the nurse was not involved in a nursing process activity (e.g., walking down the hall). A direct care disruption was an interruption occurring when a direct care activity (e.g., medication administration, patient assessment) was interrupted. An indirect care disruption occurred when an indirect care activity (e.g., documentation) was interrupted. RNs averaged 30 interruptions per shift. In addition, 47 percent of the interruptions occurred during the intervention step of the nursing process.

Table 1. Interruptions for single RN observation (RN#3)

| Interruption | Time | Description of interruption | Location | Type | Nursing process | Cognitive stacking measure: # activities |
|---------------------|-------------|------------------------------------|-----------------|------------------|------------------------|---|
| 1 | 0734 | Unit Clerk inquiry | Nurses desk | Delay | N/A | 5 |
| 2 | 0808 | Paged | Patient room | Disrupt direct | Intervention | 10 |
| 3 | 0852 | RN inquiry | Nurses desk | Disrupt indirect | Intervention | 18 |
| 4 | 0853 | Patient inquiry | Nurses desk | Disrupt indirect | Intervention | 19 |
| 5 | 0935 | MD rounds | Patient room | Disrupt direct | Intervention | 18 |
| 6 | 0941 | Paged | Patient room | Disrupt Indirect | Intervention | 18 |
| 7 | 0957 | Answers phone | Patient room | Delay | N/A | 17 |
| 8 | 1010 | Responds to patient call out | Hallway | Delay | N/A | 17 |
| 9 | 1014 | Computer malfunction | Patient room | Delay | N/A | 17 |
| 10 | 1021 | Unit Clerk report | Nurses desk | Disrupt direct | Planning | 17 |
| 11 | 1104 | MD inquiry | Nurses desk | Disrupt direct | Planning | 19 |
| 12 | 1105 | Unit Clerk inquiry | Nurses desk | Delay | N/A | 18 |
| 13 | 1239 | Computer malfunction | Patient room | Delay | N/A | 14 |
| 14 | 1248 | Paged | Patient room | Delay | N/A | 14 |
| 15 | 1359 | Patient inquiry | Hallway | Delay | N/A | 15 |
| 16 | 1451 | Unit Clerk report | Nurses station | Delay | N/A | 11 |

Omissions in care were recorded when a planned activity identified by the RN was not implemented during the observation period. Omissions are indicated on the pathway by an asterisk (Figure 2). The RNs averaged four omissions each shift. Omissions included missed assessments, incomplete patient education, missed interventions, and failure to communicate patient information to a health care colleague. None of the omissions led to a known negative patient outcome.

The accumulative cognitive stacking measure identified at any point in time the number of activities still needing completion by an RN. During the observational period, the fewest number of activities accumulated by an RN was 11 and the greatest number of activities accumulated by an RN was 21. Calculations were made to show the cognitive load at the time each interruption occurred and at the time of any omission in care. The accumulative cognitive stacking measure for RN #3 at the time of each interruption is shown in Table 1, and each omission in Table 2. Omissions for RN #3 occurred with a cognitive stacking load of 16, 18, 17, and 16 respectively. A time-weighted average

cognitive stacking load was also computed for the entire observation period. The average cognitive stacking load for RNs was 15 activities. For greater than 80 percent of each observation period, RNs had more than 13 accumulated activities.

Table 2. Omissions for single RN observation (RN #3)

| Omission | Time | Description of Omission | Cognitive stacking measure: # activities |
|------------|------|---|---|
| Omission 1 | 0813 | RN did not manage patient elimination problem | 16 |
| Omission 2 | 0908 | RN did not increase patient fluid intake | 18 |
| Omission 3 | 0949 | RN did not increase patient activity by moving patient into chair to improve lung expansion | 17 |
| Omission 4 | 1320 | RN did not report patient's perception of neck irritation | 16 |

Discussion

The combination of HFE and qualitative data provide a rich database for analyzing the nature of a nurse's cognitive work and the potential influence of environmental factors. The cognitive pathway offers a new perspective for understanding the activities of nursing care and the pattern in which activities are conducted by an RN. Furthermore, the cognitive pathway reveals the multidimensional complexity of nursing practice and provides researchers a tool to show the association of interruptions and omissions in care with the nurse's ability to focus on patient care priorities.

Data from the task analysis revealed a high proportion of nursing activity being spent on patient contact and communication. The cognitive pathway elucidates upon these data and shows that patient contact involves assessing patients' initial clinical conditions and newly developed signs and symptoms; judging the need for nursing care intervention; implementing nursing care measures; and evaluating the effects of therapy. Communication involves consulting with other health care providers; providing patient education; and delegating patient care activities to assistive personnel.

The nature of a nurse's cognitive work requires attentiveness to patient priorities and changing needs. However, the pathway shows that a nurse frequently shifts cognitively from patient to patient. In Figure 2, between the time frames of 0837 and 0850, the RN shifted back and forth between patients 17A and 17B four times in 13 minutes. After identifying priorities for 17A, the RN shifted to patient 17B to begin assessment. Then, as a result of an interruption, the RN shifted back to 17A to perform an intervention. Finally, the RN returned to 17B to complete the assessment, diagnosis and planning steps. Pathways show the RN's resilience in completing nursing process activities, but it also shows the critical

nature of the RN's work and the RN's vulnerability to making errors or omissions when cognitive shifts occur.

Clearly, cognitive shifts occur in response to patients' needs, organizational style of the RN, and environmental demands. For example, RNs will shift cognitively when a patient's condition changes, therapies are due to be administered, or patients' requests require attention. The cognitive pathways revealed different patterns in the way the three RNs approached their work. One RN systematically visited each patient during the beginning of a shift for an initial assessment. Another one visited patients more sporadically, combining assessment with other nursing process activities. To date, we have not found an association between the pattern of a cognitive pathway and omissions in care, but more data is necessary to examine this possibility. Cognitive shifts between patients occur frequently throughout a shift of care and demonstrate the challenge a nurse has in remembering the priorities and activities planned for a group of patients. Maintaining focus on the priorities and needs of multiple patients requires organizational as well as sharp "working memory" skills.¹³ As a nurse encounters each patient situation—whether it is direct patient contact or a consultation, there are activities and priorities that accumulate and require attention. The nurse uses the organizational skill of stacking to determine which activities to complete and which should remain on hold. The high cognitive stacking load achieved by the RNs in our observations raises concern. With an average cognitive stacking load of 15 activities, it is important to understand whether this affects an RN's ability to control attention so as to maintain information about the stacked activities in an active, quickly retrievable state. Conceivably a high cognitive stacking load may override the nurse's ability to appropriately attend to a given patient's priorities. Similarly, a high stacking load may lead to errors or omissions, particularly when further complicated by a high frequency of cognitive shifts and interruptions.

Retaining and remaining attentive to a high cognitive stacking load is not the same as using short-term memory (e.g., having a limited number of items 97 ± 2) for later recall.¹³ Cognitive psychology describes the quality of working memory capacity as using attention to maintain or suppress information. An individual's working memory capacity has been found to correlate with performance on higher order cognitive tasks such as reading comprehension and reasoning.¹⁴ Although we did not obtain a measure of working memory capacity for the RNs, our findings suggest further exploration of this issue is necessary. It is also important to understand the strategies nurses use to attend to or retain long lists of priorities. We observed RNs using strategies to assist in the recall of activities and priorities. Most RNs used memory aides (e.g., report organization forms or message pads) to keep track of their activities that comprised a cognitive stacking load. Observations of one RN revealed that the nurse used a system of different colored highlighters to code the various activities she needed to perform. Eventually, findings from this research may lend insight into the appropriate technological support or task organization skills that would enhance RNs' ability to manage high cognitive loads.

The measurement of a cognitive stacking load lends perspective to the stress nurses face in trying to respond to patients' multiple needs in a timely and efficacious way. Questions raised by our research are numerous. Is there a tolerance level at which nurses are unable to add to a stacking load? Is there a relationship between the number of stacked activities and patient acuity? Is the stacking load a function of a nurse's organizational skills? It is important to understand that a nurse's ability to structure and organize information cognitively affects clinical decisionmaking and potentially affects patient outcomes. The cognitive psychology literature suggests that nurses who have a lower working memory capacity may be more likely to make errors when they have a high cognitive load.

Our findings reinforce what previous researchers have found in regard to the high frequency of interruptions in the acute care environment. One interesting finding was that the two experienced RNs had an average of 37 interruptions, while the one inexperienced RN had only 16 interruptions. The two experienced RNs also had charge nurse responsibilities in addition to a full patient care assignment. The qualitative observations revealed that senior RNs, particularly those in charge, are interrupted frequently by questions or requests from junior staff members. Overall, 34 percent of the observed interruptions were attributed to queries from health care colleagues or patient's families. Ultimately, observations of additional RNs will allow researchers to analyze whether there is an association between interruptions and omissions or errors in care.

Omissions in care were relatively few. None of the omissions that occurred during our observation had identifiable negative patient outcomes. Omissions occurred at various times with respect to a nurse's cognitive stacking measure. For example, an omission occurred with a nurse's cognitive stacking as low as 5 and as high as 20. Further research is necessary to determine the relationship between omissions and cognitive stacking load.

Conclusion

To date, the analysis of the conduct of patient care activities has largely relied on HFE techniques. Because the work of nursing is nonlinear, HFE techniques alone cannot accurately portray the complicated context within which nurses deliver patient care. The merging of HFE techniques with qualitative observations has created a new perspective for researchers to consider how best to study the nature of errors in the acute care environment.

Significant research has been conducted in an attempt to understand the relationship between nurse staffing and the quality of care in hospitals.^{15, 16, 17} Questions arising from this research suggest that the ratio of RNs to patients may be a critical factor in determining whether patients experience positive outcomes. Certainly understaffing is a threat to patient safety. However, merely increasing the numbers of RNs on a patient care unit may not be a panacea if the environment in which RNs work is not conducive to clinical decisionmaking. Better understanding is needed with respect to the conditions in an acute care

environment that affect clinical decisionmaking. Ebright and colleagues⁶ found that after examining the daily work routines of registered nurses, a series of gaps and discontinuities distracted the RNs from focusing on critical clinical reasoning. The researchers found numerous work patterns that added to the complexity of nurses' work including disjointed supply sources, missing supplies, repetitive travel, and interruptions. In addition, Ebright found RNs making tradeoffs in an effort to balance conflicting goals including maintaining patient safety, avoiding increasing complexity, preventing getting behind, and maintaining patient and family satisfaction.⁶ Our research compliments that of Ebright's and builds upon the understanding of the complex nature of a nurse's work. Researchers can no longer simply focus on task-related processes of patient care, but must study the nature of clinical decisionmaking and the impact of the work environment.

The development of cognitive pathways is labor intensive. In the future, the research team will conduct additional observations over shorter time frames so that sufficient data can be compiled to examine the association between cognitive shifts, interruptions, cognitive load, and the incidence of errors and omissions in care. Further work is also needed to explore the relationship of variables such as nurse experience, type of clinical specialty setting, and delivery of care models with clinical decisionmaking patterns.

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Author affiliations

PBJC Health Care, St. Louis (PP, LW, JS). Washington University School of Medicine, St. Louis (SB, DG).

Address correspondence to: Patricia Potter, R.N., Ph.D., 12977 Wallingshire Ct.; St. Louis, MO 63141; e-mail: Pap1212@bjc.org.

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